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Suturing the myotendinous junction in total hip arthroplasty: A biomechanical comparison of different stitching techniques

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ABSTRACT

Background: The repair of the myotendinous junction following total hip arthroplasty is challenging as this region is the weakest part of the muscle structure. This study investigated the mechanical behaviour and the mode of failure of different suturing techniques of the myotendinous junction. A new asymmetrical stitch was compared to two widely used techniques, i.e. the simple stitch (two loops in parallel) and the figure-of-eight stitch.
Methods: The ovine triceps brachii myotendinous junction was selected as the experimental model. Each technique was sewn in muscle belly on one side and in a polyester belt (no-tendon configuration) or in thin tendon (full configuration) on the other side. The former was chosen to determine the grasping power of the stitch on the muscle despite the tendon quality, the latter to simulate a very thin gluteus medius tendon.
Findings: The new stitch showed a higher ultimate strength (+40%) compared to the two controls in the no-tendon configuration. In the full configuration, no significant increase was observed, although failure of the new stitch always occurred at the tendon side. Furthermore, the new stitch does not alter the stiffness of repair.
Interpretation: The new stitch has a higher grasping power on muscle belly than the single passing-through stitches thanks to the multiple fixation points, which better distribute the load in the tissue. However, such performance can be fully exploited only in the presence of good quality tendons.

1. Introduction

Total hip arthroplasty (THA) can be performed using different approaching techniques (Berger, 2004; Brimer, 2014; Kelmanovich et al., 2003). All approaches, with the exception of the anterior approach, require splitting and dissecting/detaching muscles in order to obtain access to the hip joint even if a minimally invasive surgery is used (Berger, 2004; Kennon et al., 2004). In all cases where a partial or total sharp incision of a muscle at its myotendinous junction is required, the surgeon must repair the resected asymmetrical structures using sutures (Kennon et al., 2004; Smith et al., 2014).

Soft tissue must be adequately sutured. In the early postoperative period, the repaired structures—if involved in hip stability—must play their role to reduce the risk of dislocation (Brooks, 2013; Patel et al., 2007; Yarlagadda and Jones, 2009) and/or withstand loading condition due to early mobilization of patients (Tayrose et al., 2013). In fact, it is common to start physiotherapy one or a few days after surgery, the effective period depending on hospital protocol and patient conditions (Berend et al., 2004; Martin et al., 2013). Repair failure may delay the formation of scar tissue and also impact on the functional recovery of the muscle (Bergin et al., 2011; Von Roth et al., 2014). Even in case of delayed mobilization, muscle contraction could cause local damage in repaired tissues (Burkhart et al., 1997).

In literature, different methods for suturing tendons have been proposed (Lee et al., 2012; Rawson et al., 2013). In general, biomechanical studies show that increasing the complexity of repair increases its strength and sometimes its stiffness (Hapa et al., 2013; Ketchum, 1985; Lawrence and Davis, 2005; Rawson et al., 2013). However, too complex repair may further damage the tissue and be time demanding (Mashadi and Amis, 1991; Rawson et al., 2013). Therefore, the optimal stitch should: (i) assure adequate grasping power (defined as the ability to transfer tensile load at the suture-tissue interface) without strangulating the tissue (Ketchum, 1985; Miller et al., 2007); (ii) be able to distribute the load to avoid stress raiser in soft tissue and, finally, risk of local damage (Burkhart et al., 1997); (iii) ensure quick reproducibility, both in terms of sewing and training (Moy et al., 1992). The repair of the myotendinous junction is further challenging as this region is the weakest part of the muscle structure (Garrett, 1990). Additionally, the suturing techniques must account for the differences between the tendon and muscle tissue (Arampatzis et al., 2010; Knudson, 2007). Therefore, the optimal compromise should be an asymmetrical simple suture pattern using the principle of load distribution through multiple fixation points in the soft tissue (Gerber et al., 1999; Kragh et al., 2005).

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The purpose of this study was to determine the mechanical properties of a novel asymmetric suturing techniques and compare them with the stitches commonly used for the myotendinous junction closure in total hip replacement.

2. Methods

2.1. Tissue samples

The sheep triceps brachii muscle was selected as an experimental model for four reasons: (1) the muscle anatomy resembles the human gluteus medius in shape. In fact, both muscles have broad origins and converge radially towards the insertion point onto the long bone (olecranon process of the ulna or great trochanter of the femur) (Gottschalk et al., 1989). Therefore, both muscles narrow down to a short, flattened collagenous tendon. However, the sheep triceps brachii muscle is smaller in size compared to the human gluteus medius and this represents an advantage (see points 2 and 3). (2) Due to the reduced width—typically in the range of 1.5–3.0 cm, i.e. narrower than a human gluteus medius (Dishkin-Paset, 2011, p. 31; Dishkin-Paset et al., 2012; Robertson et al., 2008)—of the sheep triceps brachii tendon, the myotendinous junction can be repaired sewing one stitch, thus allowing the comparison of the stitch performance. (3) The reduced thickness of the triceps brachii tendon—typically in the range of 2–5 mm—represents the worst-case scenario by simulating a thin gluteus medius tendon—typically in the range of 5–7 mm (Dishkin-Paset, 2011, p. 31; Robertson et al., 2008). (4) The triceps brachii muscle can be easily and quickly detached and isolated avoiding the risk of fibre damage or degradation during handling.

Triceps brachii muscles were collected from mature sheep (18–24 months of age) at the local slaughterhouse. No ethical authorisation was necessary since tissue samples were collected from animals killed for alimentary use. At sacrifice, both the forelegs were dissected at the level of the humeral head. The samples were immediately frozen and preserved at −20 °C. All samples underwent testing within one week from the date of collection.

2.2. Suturing techniques

Three suturing techniques were investigated in the present study. The first two techniques—simple stitch (two loops in parallel) and the figure-of-eight stitch—are widely used in clinical practice for suturing soft tissues (Hansen et al., 2011; Kluba et al., 2012; Miozzari et al., 2010; Oinuma et al., 2014). The last suturing technique involves the use of a novel stitch, hereinafter referred to as double loop (DL) stitch. On the muscle side, the stitch grasps a wider soft tissue volume through multiple fixation points, as suggested in by other authors (Kragh et al., 2005). However, a single thread is necessary to sewn the DL stitch. On the tendon side, it is a middle ground between the Mattress and the modified Mason–Allen stitch (Fig. 1).

The same experienced surgeon (SA) performed all repairs. Each stitch was sewn about 10 mm from the cut level (Fig. 2). Likewise, the target transverse dimension was 10 mm. A number 2 polyglactin 910 suture (Coated Vicryl, Ethicon Inc., Somerville, NJ, USA) was used for all stitches. The threads were closed by means of a 2 = 1 = 1 = 1 = 1 knot (Muffly et al., 2010).

2.3. Experimental model

Two different experimental models were used. The first model (no-tendon configuration) was designed to determine the grasping power of the stitch on the muscle. A polyester belt replaced the tendon to make sure that repair fails by suture cutting through the muscle. Therefore, the thread was passed through the muscle belly on one side and the polyester belt on the other side (Fig. 2). The second model (full configuration) involves testing of the whole triceps brachii muscle with its insertion in the ulna. The thread was passed through the muscle belly on one side and the tendon on the other side (Fig. 2). As mentioned above, the sheep tendon is thinner and narrower than that of a human gluteus medius, therefore representing a poor-quality tendon.

An *a priori* power analysis was performed, using data from the literature about variability in mechanical performance of the simple stitch (Bungaro et al., 2005; Ma et al., 2004), to determine the minimum sample size needed to detect a large effect (effect size 0.5). Type I and type II errors were set to 0.05 and 0.20, respectively. The calculated minimum sample size was 10. To take potential experimental problems into account, the sample size was increased by one unit. Therefore, eleven repetitions were planned for each testing configuration and each stitch type.

2.4. Experimental procedure

Each single limb was placed into a refrigerator (about 4 °C) the day before testing. On the day of testing, the pelt was incised and removed

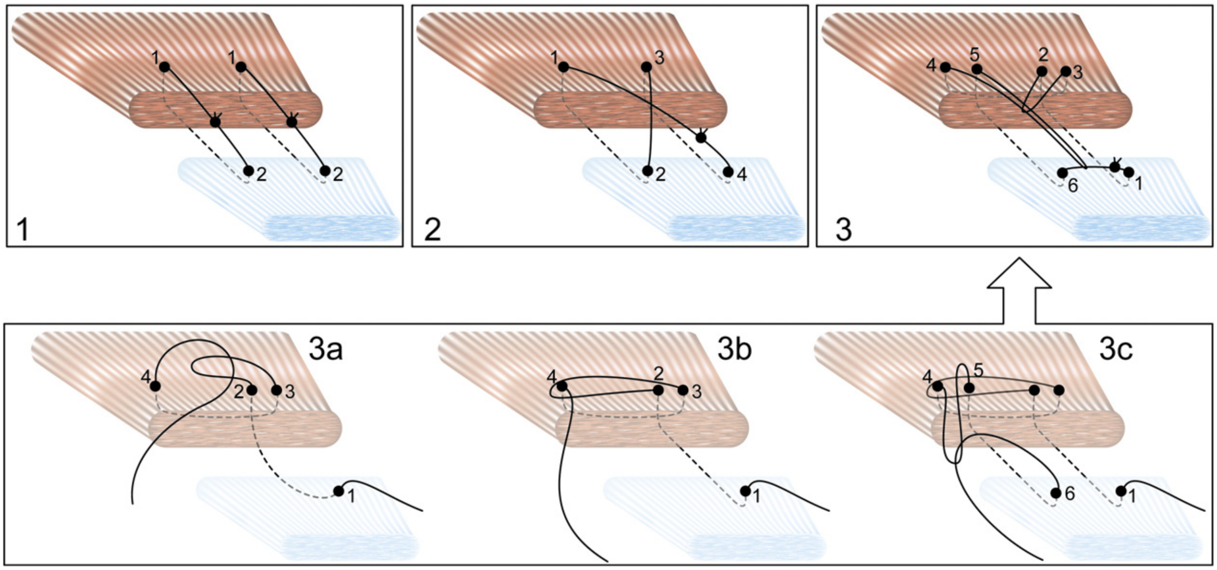

Fig. 1. (1) Two single loops in parallel; (2) the figure-of-eight stitch; (3) the DL stitch: (3a), (3b), and (3c) show three different steps of sewing the DL stitch.